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Study II: Forage Development and Evaluation Job 1:
American Shad Introduction to Brownlee
Reservoir: Evaluation of Proposal

By

Jeff C. Dillon
Fishery Research Biologist
and

Debby Myers
Fishery Technician

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ABSTRACT

American shad *Alosa sapidissima* were investigated as potential forage fish for Brownlee Reservoir. We evaluated the possible applications of stocking pre-spawn adult American shad in the Snake River above Brownlee and allowing natural reproduction to produce a year-class of forage. The primary objective was to provide additional forage species for smallmouth bass *Micropterus dolomieui*. The utility of larval and juvenile American shad as forage is largely undocumented, but life history traits indicate they may provide seasonal forage for smallmouth bass, white crappie *Pomoxis annularis*, black crappie P. *niqromaculatus*, and possibly rainbow trout *Oncorhynchus mykiss* in Brownlee. Pre-spawn adult American shad could be collected at the fish ladders of Lower Granite or Ice Harbor Dams around July 1 and released above Brownlee. Larval and juvenile American shad should disperse throughout the reservoir. American shad outmigration is keyed to a decline in temperature to about 15°C, which occurs in mid-October in Brownlee. We do not know whether juvenile American shad will be able to outmigrate from Brownlee, but successful outmigration may result in an expanded American shad run up to Hell's Canyon Dam. Establishment of a landlocked population of American shad in Brownlee is not desired. The cold thermal regime of Brownlee should prevent establishment. The smaller size classes (<200 mm) of smallmouth bass appear most likely to benefit from American shad forage. Introduction should be further considered, but a current growth evaluation of smallmouth bass should be completed first. If growth rates have declined since initiation of the 12-inch minimum size limit, managers should decide whether other options would be more appropriate than forage manipulation to improve smallmouth bass growth rates. A plan for monitoring results should also be developed and concerns for possible interactions with anadromous species addressed before any introduction occurs.

Authors:

Jeff C. Dillon
Fishery Research Biologist

Debby Meyers
Fishery Technician

ASABST

AMERICAN SHAD INTRODUCTION TO BROWNLEE RESERVOIR
EVALUATION OF PROPOSAL

INTRODUCTION

In 1989, the Fishery Management Section identified Brownlee Reservoir as a site for proposed forage introductions, primarily to enhance the smallmouth bass fishery. Emerald shiner Notropis atherinoides introduction was initially proposed, and an evaluation of this proposal was completed January 10, 1990. Early on in the discussions of potential forage fish for Brownlee Reservoir, American shad Alosa sapidissima was also considered. The proposal and evaluation procedures used here follow the format developed by Ortmann (1986). As with emerald shiners, no formal proposal (Phase III) document for American shad introduction to Brownlee Reservoir was provided. Much of the information required for Phases I-III is included in the emerald shiner evaluation (Dillon and Myers 1990, Job 1), and will not be repeated here.

The information presented in this report was gathered primarily through a comprehensive literature review. Letters of inquiry were also sent to state natural resource agencies within the current distribution of American shad. The literature review summary, literature cited, and copies of the letter of inquiry and responses are attached (Appendices A and B).

American shad were not on the original list of potential forage species (Phase II) assembled by Reininger (1984), presumably because of their large size as adults. However, as discussed below, we are primarily interested in the value of juvenile American shad as forage.

PHASE III (Proposal)

1. The validity of need section is presented in the emerald shiner evaluation (Dillon and Myers 1990, Job 1).

2. Species and numbers proposed for introduction

   American shad were investigated as potential forage fish for Brownlee Reservoir. The approach would be to stock pre-spawn adult shad in the Snake River above Brownlee allowing natural spawning to produce a year-class of larval and juvenile shad forage. Post-spawning mortality of adult American shad is high, and establishment of adults in the river or reservoir is not anticipated or desired. A summary of life history information, with emphasis on larval and juvenile shad, is presented in Table 1.

Table 1. Life history information for American shad.

Maximum size		
	Adults	Males 500 mm, females 600 mm
	Juveniles	Outmigration typically occurs at 51-76 mm, but up to 100 mm
Spawning	Temperature	12-21°C
	Habitat	Anadromous. Adults ascend rivers in spring and spawn in open water of large streams. Water velocities 0.3-0.9 m/sec. Eggs are broadcast, sink to the bottom. Minimum dissolved oxygen 4.0 mg/1 in spawning areas. Hatch in 8-12 days at 11 to 15°C; 3-6 days at 17°C.
		Post-spawning mortality 70 to 90%
	Fecundity	150,000 to 500,000 eggs/female
Habitat preference		Larvae subject to drift. Larvae and juveniles found in eddies and backwaters of rivers, and bays and backwaters of reservoirs, become more pelagic at 1 month. Juveniles remain in freshwater until fall. Outmigration keyed by decline in water temperature to approx 15°C.
Temperature tolerance		Upper tolerance 26°C. Juvenile mortality high at 5°C and below.
Diet and feeding behavior		
	Larvae	Selective for larger cladocerans, copepods, and chironomid larvae. May cannibalize smaller larvae.
	Juveniles	Opportunistic feeder in the water column. Larval and adult insects and larger zooplankton. Feed at bottom or middle of water column during day, rising near surface at night.

Table 1. Continued.

Competition	As larvae and juveniles may compete with other littoral planktivores for first month, then with pelagic planktivores. Adults are not likely to establish in fresh water. If abundant, could impact crappie and trout.
Fresh water predators	Very little documentation. Seasonally dominant prey item for northern squawfish in lower Columbia. Probably used by walleye and smallmouth and largemouth bass in rivers and estuaries of the East Coast.

Stocking pre-spawn adult fish to create a year-class of forage-size fish with no expectation of establishment has been done elsewhere. Wyoming Game and Fish regularly stocks pre-spawn adult gizzard shad *Dorosoma cepedianum* into several of their large reservoirs. Gizzard shad, like American shad, are very fecund, and Wyoming reports excellent production of forage from stocking just 500 to 1,000 adults in large (>4,000 hectares) reservoirs. The cold thermal regime in these Wyoming waters inhibits the growth of young-of-the-year (YOY) gizzard shad, resulting in virtually no recruitment to adult size. A similar approach with American shad in Brownlee might provide a seasonal boost in forage production where forage fish are currently lacking (Dunsmoor and Bennett 1986). Most of the adult American shad would be expected to die after spawning. Juveniles would probably attempt to migrate out of the reservoir in mid-October as temperatures fall to 15°C, but we don't know whether they could outmigrate given the deep withdrawal at Brownlee. Juveniles that remain in the system would probably suffer high mortality due to the cold winter temperatures in Brownlee (3.3 to 5.5°C) and in the Snake River above (1.0 to 3.0°C).

The possibility of manually spawning American shad was investigated to see if placing fertilized eggs in the Snake River would be an option to planting pre-spawn adults. Although American shad fecundities are high, eggs do not mature simultaneously, and normal egg-taking procedures yield only 20,000 to 30,000 eggs per female. Therefore, if eggs were obtained by this method, it would take about 1,800 females to provide the same number of eggs spawned naturally by about 200 females. For this reason, transfer of pre-spawn adults appears to have the most potential for efficient introduction of juveniles.

Smallmouth bass growth rates in Brownlee were higher than average for this latitude for all but Age I fish (Rohrer 1984). Dave Bennett (University of Idaho, College of Forestry, personal communication) feels that the availability of YOY American shad would coincide with first piscivory of YOY smallmouth bass. Smallmouth in Brownlee typically spawn in mid-May, with most YOY off the nest by early June. First feeding is on zooplankton, and a switch to larger prey items should occur by late summer. However, Bennett and Dunsmoor (unpublished M.S. thesis) found that most of the yearly caloric intake for smallmouth bass <200 mm came from zooplankton, indicating a lack of larger prey for the smaller bass. American shad arrive at Lower Granite Dam in late June and probably spawn in late June to mid-July in the Lower Granite pool. Transferring pre-spawn adult shad to Brownlee Reservoir should allow production of forage at a time when it is most needed by YOY and other size classes of smallmouth bass. Growth of YOY smallmouth bass might improve with increased availability of larger forage items. The larval and juvenile shad would, however, probably be available for only a short period (approximately one month), as after this time they become more pelagic. Christine Moffit (University of Idaho, College of Forestry, personal communication) reported catching few American shad in the littoral zone of the Lower Granite pool after August.

After moving offshore at an approximate size of 40 mm, juvenile American shad may provide additional forage for white crappie. Because they tend to prefer warmer water, American shad would probably be unavailable to rainbow trout in Brownlee Reservoir during the summer, but juvenile shad which fail to move out of the system may provide forage for trout in the fall as surface temperatures decline.

The number of adult American shad necessary to produce significant forage for Brownlee is unknown. The surface area of Brownlee is approximately 6,000 hectares. Wyoming Game and Fish reported excellent forage production by stocking 500 to 1,000 adult gizzard shad in 8,000 hectare Seminoe Reservoir (Bill Wichers, personal communication). The fecundity of American shad is comparable to that of gizzard shad. An initial target of 500 to 1,000 American shad for Brownlee is appropriate.

3. Potential sources

American shad could be collected at the fish ladders of Ice Harbor or Lower Granite Dam around July 1 at the peak of the spawning run. Adults would be transported to the Snake River above Brownlee for release.

The difficulty of transporting adult American shad may represent a major obstacle to introduction. Several agencies on the East Coast involved with American shad restoration projects noted that one of their biggest problems was transport mortality of relocated fish. Transport in standard hatchery trucks resulted in very high mortality, and most agencies now use insulated circular tanks with pumps maintaining a constant current to keep the shad swimming. Richard St. Pierre (Susquahanna River Anadromous Fish Restoration Committee, Harrisburg, PA, personal communication) recommends a minimum of 15 mg/1 oxygen (or saturation) and 1% uniodized salt solution, plus an anti-foam agent when hauling American shad. Hauling density should be low (100 to 150 adults in an 8-foot diameter by 4-foot deep tank). He reports that American shad can be transported up to 300 km this way with 90% survival. The haul from Ice Harbor or Lower Granite Dams to Brownlee would be approximately 380 or 460 km, respectively.

PHASE IV (Proposal Evaluation)

1. & 2. Identification of target water for introduction and proposed species - see above.

3. Suitability of the habitat for establishment of a self-sustaining population in quantity adequate for the intended purpose.

Establishment of a landlocked population of American shad in Brownlee is not desired. Adult shad would be too large to serve as forage and would compete with existing planktivores in the reservoir. It is thought to be extremely difficult to successfully landlock American shad given the hundreds of failed attempts throughout the United States (Richard St. Pierre, personal communication). Low winter temperatures in Brownlee Reservoir (3.3 to 5.5°C) and in the Snake River above the reservoir (1.0 to 3.0°C) appear likely to prevent establishment.

Although juvenile American shad tend to outmigrate as water temperatures drop to 15°C, the lack of current in mainstem Brownlee may prevent shad from orienting themselves for downstream migration. The withdrawal from Brownlee is relatively deep, and might also prevent successful outmigration of shad. If this is the case, juvenile shad may remain in the system into the fall, and winter mortality would be expected to prevent establishment. The high post-spawning mortality should prevent any significant buildup of introduced adults, even if transplants occurred frequently.

We have identified no limitations for American shad spawning in the Snake River above Brownlee. Depth and substrate are probably not important factors in determining spawning location. The preferred water velocity for spawning is 0.3 to 0.9 m/sec and should be available in the Snake River.

The amount of larval and juvenile shad forage production that might occur will vary with the number of adults stocked and spawning success. At this time, we have no way to predict what the total production might be. Wyoming reports that their practice of stocking pre-spawn adult gizzard shad results in excellent production of YOY forage fish, providing abundant prey even in some of their larger reservoirs. Our approach with American shad seems to parallel their efforts with gizzard shad, but we still have no concrete basis on which to predict results. If introduction proceeds, it will be important to monitor shad production related to numbers of adults stocked so that stocking guidelines can be developed.

4. Predicted impact on total trophic chain (plankton to predators).

It is impossible at this stage to predict the abundance larval and juvenile American shad might reach in Brownlee and the resultant impact on the zooplankton community. Because larval and juvenile American shad remain in the littoral zone for only about one month, their impact, if any, on littoral zooplankton will be short-term. As they become more pelagic, juvenile shad may compete with trout and crappie. If shad fail to outmigrate, they may compete with trout into the fall, but this would also extend their availability as forage.

The level of competition between game fish and larval and juvenile American shad will depend on shad abundance. Regulation of juvenile shad densities should be possible through changes in adult stocking rates. If they overwinter, however, the introduction would be irreversible, as occurred in a very similar Millerton Reservoir. Shad establishment could have severe negative impacts on the existing fishery.

5. Predicted final distribution of the species.

As noted above, there is little chance that American shad will persist in Brownlee or in the Snake River above the reservoir. If they do, results would be irreversible. It is likely that shad spawned in the system, if they can successfully outmigrate, will attempt to return as adults. American shad are already found in the lower Snake River as far up as the Lower Granite pool. Introduction to Brownlee may result in spawning adults migrating upriver to Hell's Canyon Dam where they are not currently found. Further upstream migration is blocked by the dam. Water temperatures in the Hell's Canyon Dam tailrace reach 18 to 21°C in July, so successful American shad spawning in this stretch of the river is likely.

6. Predicted impacts on fish populations in connecting waters.

One concern with potentially expanding the run of American shad is their presence in fish ladders of the lower Columbia and Snake Rivers. American shad accumulate in some of the ladders in spring and may block passage for anadromous salmonids. It is doubtful that introduction to Brownlee would significantly increase the size of the American shad spawning run, but the concern should be addressed prior to introduction efforts.

7. Predicted benefit to target fishery.

If adult American shad are stocked around July 1, larvae would probably begin to appear in Brownlee within two weeks. The larvae can swim well and should disperse throughout the reservoir. Smallmouth bass of all sizes would probably feed on the larvae and juveniles, but YOY smallmouth seem likely to benefit most from a new forage item. Dave Bennett (University of Idaho, personal communication) feels that growth of smallmouth bass <200 mm in Brownlee is more acutely limited by forage availability than are the larger size classes of bass. American shad can be stocked to provide YOY abundant enough to contribute significantly to YOY bass diets when they shift to piscivory. Growth gains for larger smallmouth bass would probably be minimal due to the short-term availability of American shad.

Juvenile shad become more pelagic at approximately one month at an average size of about 40 mm. Thereafter, they are only occasionally found in littoral areas. They would tend to remain above the thermocline and would be unavailable to trout in the summer, but may provide additional forage for white crappie.

Water temperatures in Brownlee drop to 15°C around mid-October, which would normally trigger outmigration of juvenile American shad. We don't know if shad will be able to outmigrate from the system given the lack of current and the deep withdrawal. If juveniles remain in the system into the fall, they may provide additional forage for rainbow trout after destratification. If some shad can outmigrate, they may provide a seasonal boost in forage availability in Oxbow and Hell's Canyon Reservoirs and in the Snake River below.

It will be important to document American shad spawning success and utilization by smallmouth bass or other predators in Brownlee to justify continued introductions in subsequent years. If no evidence of utilization is found, or if gains in game fish production are not realized, stocking can be discontinued and the shad allowed to disappear from the system.

8. Is disease clearance likely?

Richard St. Pierre (personal communication) noted that American shad in the Columbia River showed some incidence of INN. We found no other information on diseases or parasites of American shad, and we recommend that disease-free status be confirmed before any introduction takes place.

9. Are data adequate for an informed decision?

The information summarized herein indicates that American shad would be able to successfully spawn in the Snake River above Brownlee and could produce abundant forage. There is, however, a lack of information regarding the use of American shad as forage by smallmouth bass, crappie, and trout. Our expectation that shad would provide forage comes from the life history information and is not supported in the literature. We have some doubt as to whether American shad would be able to outmigrate from Brownlee. Based on winter temperatures in Brownlee and the Snake River above, and on previously unsuccessful attempts to establish landlocked population of American shad elsewhere, we believe that American shad has a very low risk of persistance as a landlocked form in Brownlee. This provides a critical link leading to the recommendations below.

10. Do data confidently support introduction?

Based on the low risk of establishment in Brownlee and because they are already present in downstream waters, American shad represent a relatively safe source of forage. Although we found no documented evidence of American shad providing forage for smallmouth bass or white crappie, shad life history information indicates they may be available to both species in late summer and early fall. Agencies on the East Coast felt that larval and juvenile American shad might be an important seasonal forage for several riverine predators including smallmouth bass, but their support for this was largely anecdotal.

If juvenile American shad fail to outmigrate from Brownlee, they may provide additional forage for rainbow trout in the fall. Because of their seasonal availability to trout, American shad alone would probably not provide an adequate forage base for the more piscivorous strains of rainbow trout.

The smaller size classes (<200 mm) of smallmouth bass appear most likely to benefit from additional forage. If American shad were stocked abundant enough to contribute YOY to the diet of YOY bass, improved growth and survival may result. However, the smallmouth bass population in Brownlee does not appear to be limited by recruitment and the growth rates are relatively good (Rohrer 1984), making the need for additional bass forage questionable. As noted, the short-term availability of American shad may limit their value as forage for larger bass. Before any forage introductions proceed, current growth evaluations on smallmouth bass in Brownlee should be completed. If growth rates have declined since the initiation of the 12-inch minimum **size** limit, alternate regulations would be another management option.

The above information supports further consideration of introduction on an experimental basis, but with some qualifiers. A current growth evaluation for smallmouth bass should be completed first, and management options other than forage manipulation should be evaluated. If introduction proceeds, we should make a commitment to monitor American shad spawning success, contribution to fish diets, and competition with game fish. The new smallmouth bass growth data should be used as a baseline by which we can measure benefits. Documenting the value of American shad as forage and the possible benefits to the fishery will be of interest to fishery managers throughout the range of American shad. Adequate documentation will also be necessary to justify the costs incurred by yearly transplant efforts. If we find that American shad do not provide forage, or that gains to the fishery are small compared to costs, we can halt transplant efforts with the expectation that shad will disappear from Brownlee.

Introducing American shad to Brownlee may result in expansion of their spawning range up the Snake River to below Hell's Canyon Dam. Managers will have to determine whether this possible expansion would affect fish ladders downstream, and whether this concern is enough to reject introduction. There is also **a** low risk of establishment of natural populations which will have to be weighed against anticipated benefits.

11. Recommendation for/against the proposal.

American shad are not a good candidate for forage in Brownlee at this time because bass growth rate information is unavailable and the benefits of a forage are unknown for increasing size of smallmouth bass. American shad are a beter option for Brownlee than emerald shiner because they probably will not establish and their presence is reversable with cessation of stocking. Prior to any introduction, the similarities between Millerton Reservoir (only known landlocked shad population) and Brownlee need determined. The concern for expansion of American shad into Hell's Canyon and the possible conflicts with anadromous fish should also be addressed prior to introduction.

SHADEVAL

Appendix A. Literature summary for American Shad.

DESCRIPTION

The American shad Alosa sapidissima has a compressed fusiform shape, single soft-rayed dorsal and anal fins, a deeply forked tail fin, strongly serrated ventral edge of the abdomen, and large scales that are easily lost (Walburg and Nichols 1967). The shad are silvery white in color with a bluish green metallic luster on their back (Cheek 1961) and one or more dark spots in a longitudinal row behind the opercle (Eddy and Underhill 1979).

DISTRIBUTION

American shad were introduced into the Sacramento and Columbia rivers in 1871 and have become established along the Pacific coastline from southern California to Alaska (Scott and Crossman 1973). Shad migrate up the Columbia River and into the lower Snake River as far upstream as Lower Granite Dam (river mile 107). In 1988, 2,977 adult American shad passed through Lower Granite Dam (US Army Corps of Engineers 1989). Hells Canyon Dam is a barrier to migration of anadromous fish in the Snake River upstream of river mile 247.

Although the American shad is an anadromous species which usually spends two to five years at sea (Scott and Crossman 1973), it can successfully maintain a population in a landlocked environment (Ecological Analysts 1982). The only known freshwater population of American shad exists in Millerton Lake, a reservoir located on the San Joaquin River in California (Ecological Analysts 1982, R. St. Pierre, Pennsylvania Wildlife Commission, personal communication). Spawning site and early life habits of the landlocked population of shad found in Millerton Lake are similar to those of anadromous populations.

LIFE HISTORY

American shad spawn at night in open water (Scott and Crossman 1973). Each female lays from 100,000 to 600,000 eggs, depending on size and originating stream (Cheek 1961). The fertilized eggs are 2.5-3.5 mm in diameter, non-adhesive, and slightly heavier than water.

Hatching occurs in 8-12 days at 11 to 15°C (Scott and Crossman 1973); 3-6 days at 17°C (Bigelow and Shroeder 1953). Leach (1925) found eggs hatched in three days at water temperatures of 24°C and 12 days at 10°C, but healthy larvae are not produced at these extremes (Carlson 1966).

Larvae are 9-10 mm long at hatching (Scott and Crossman 1973). The young swim vigorously by rapid and continuous vibrations of the tail from the moment they leave the eggs (Walburg and Nichols 1967). They absorb their yolk-sac in 3-5 days (at 10-15 mm) and become particulate feeders on zooplankton (Crecco and Blake 1983, Levesque and Reed 1972, Leim 1924). The larva stage lasts about 25-35 days before larvae metamorphose into filter feeding juveniles.

Larval shad feed on cladocerans, copepods, and immature insects (Crecco and Blake 1983). Larvae of all sizes select for larger copepods and chironomid larvae. Rotifers are not **a** popular food item of shad larvae. Levesque and Reed (1972) found shad larvae stomachs contained copepods, tendipedid larvae, and tendipedid pupae with some Daphnia (57% crustaceans; 37% diptera larvae and pupae by volume). Larvae greater than 21 mm also ate their own larvae (14.4% by volume).

Juvenile shad are opportunistic feeders, selecting food more often from the water column than from the bottom or the surface (Levesque and Reed 1972). Phytoplankton is not a major food source. Stomach contents found in studies conducted by Levesque and Reed (1972) were 34% crustacea, 15% tendipedid larvae, 7% tendipedid pupae, 13% hydropsychid larvae, and 11% adult insects. There was a positive selection for tendipedid pupae. Diurnal feeding data showed a peak in stomach content volume at 8:00 pm during mid summer.

Larval and juvenile shad are frequently found associated with eddies and backwater areas during their freshwater residence (Cave 1978 from Crecco et al. 1983). All of the shad larvae, and the majority of juveniles, collected in Little Goose Reservoir by Bennett et al. (1983) were found in backwater areas (embayments and gulches).

In anadromous populations, the young spend their first summer in the river, migrating to the ocean in the fall when they are approximately 51-76 mm in length (Scott and Crossman 1973). The downstream movement of young shad appears to be influenced largely by a decline in water temperature (Chittenden 1972, Carlson 1966, Walburg and Nichols 1960). Most fish move downstream when the water temperature drops to 15°C, although stragglers can be found at temperatures below 8°C (Carlson 1966). Length of time required for outmitration is shortened by rapid water temperature drops or increases in flow or both (Sykes and Lehman 1957 from Walburg and Nichols 1960).

HABITAT REQUIREMENTS

Spawning Habitat

Temperature and water velocity are the two factors that have the most influence on shad spawning (Ecological Analysts 1982). In anadromous populations of American shad, spawning begins when water temperatures reach 12°C and peaks at approximately 18°C (Scott and Crossman 1973, Massmann 1951). In Millerton Lake, spawning begins in early May, lasting for as few as 22 days and up to 118 days. River temperatures range from 11.0 to 17.2°C during spawning (Ecological Analysts 1982). Length of spawning season is probably due to the length of time that the river is within the suitable temperature range (12 °C to 21 °C) (Walburg and Nichols 1967).

Water velocities in spawning areas of Millerton Lake are between 0.2 and 0.6 m/sec, averaging 0.46 m/sec at the surface (Ecological Analysts 1982). Similar conditions were found in anadromous stocks of American shad. Massmann (1951) found spawning occurred in water velocities between .31 and .92 m/sec, with the highest number of eggs collected from spawning areas that had velocities between .61 and .92 m/sec in the Pamunkey River in Virginia. Most spawning in the Sacramento River in California occurs at surface velocities between 0.46 and 0.61 m/sec. No shad spawned in Millerton Lake in areas of 0 velocity (Ecological Analysts 1982).

Depth and substrate are probably not important factors in determining spawning location (Ecological Analysts 1982). Although American shad frequently spawn in fluvial deposits of gravel and rubble that are continually bathed with moving water, they have been found to spawn over a variety of substrate types in both channels and in shallows (Ecological Analysts 1982).

Davis (1975) gives 4.0 mg/l as the minimum level of dissolved oxygen necessary for spawning areas. Acceptable pH ranges from 6.0 to 9.4 (Bradford et al. 1968).

Early Life Habitat

Low survival rates between newly hatched larvae and juveniles are found associated with low water temperatures (10 to 14°C), high river flows (655 - 1133 m^3/s), and low densities of river zooplankton (150-300/m^3) (Crecco and Savoy 1985).

The optimum temperature range for egg incubation is 12 to 19°C (Walburg and Nichols 1967). American shad eggs can tolerate temperature rises of 5 to 10°C in three hours within an optimum survival range of 15 to 26°C. Eggs kept for three days at 9°C died.

The upper thermal tolerance limit for shad eggs and larvae in bio-assays is 26°C (Carlson 1966). The lower thermal tolerance limit is 2.2°C (Chittenden 1972).

Young shad are unable to tolerate continued exposure to low temperatures. Chittenden (1972) found movement of young shad was sluggish, with frequent equilibrium losses at temperatures below 6°C. Most shad died when held within a temperature range of 1.7 to 5.0°C. In laboratory tests, juveniles avoided temperatures less than 8°C and strongly avoided temperatures less than 5°C (Chittenden 1972).

Ninety-seven percent hatch occurs at pH greater than 6.0. Severe crippling or larval death occurs at pH less than 5.5.

Shad can survive at dissolved oxygen levels as low as 5 mg/1 (Walburg and Nicols 1967). Davis (1975) lists 2.5 mg/1 as the oxygen threshold for shad migration through polluted areas.

APPEND-A

AVAILABILITY AND UTILIZATION

Young-of-the-year shad are morphologically and behaviorally similar to outmigrant salmonids (Maule and Horton 1984). Juvenile shad, however, are generally smaller (51-76 mm) than juvenile salmonids (150-190 mm) and emigrate in the fall (August-November).

Juveniles are generally found in backwater areas of reservoirs. Periods of high runoff may displace larvae and their zooplankton prey from the eddie and backwater areas where they are normally found to areas of high predator abundance (Savoy and Crecco 1986).

During the day, the young apparently feed below the surface and rise to the surface at night in dimming light (Maule and Horton 1984). Schools of young shad can be seen in the evening feeding on insects at the surface (Cheek 1964). Surface feeding is most evident from dusk to dark and daybreak to sunrise (Walburg and Nichols 1967).

There is very limited documentation available on the utilization of American shad as forage in the Columbia River or the Lower Snake River reservoirs. Shad have been documented as a dominant food item for Northern squawfish *Ptychocheilus oregonensis* in the tailraces downstream from the McNary and John Day Dams on the Columbia River (Gray et al. 1982). Studies conducted on both the Columbia River and the lower Snake River lack significant sampling of smallmouth bass *Micropterus dolomieui* during the period of time that American shad are available as prey (Gray et al. 1982, Bennett et al. 1983). Maule and Horton (1984) found in mid-Columbia River reservoirs that small walleye *Stizostedion vitreum* (200-400mm) primarily consume cottids (60%), salmonids (30%) and shad (5%). No walleye less than 200 mm were sampled. However, the authors believe that inclusion of this smaller size group might show an increased importance of shad in walleye diets.

American eels *Anguilla rostrata* and catfishes *Ictalurus spp*. are major predators on American shad eggs in Atlantic coast rivers, while striped bass *Roccus saxatilis* prey heavily on the young shad (Walburg and Nichols 1960).

LANDLOCKING AMERICAN SHAD

Although it is common in anadromous populations of American shad to find some fish that hold over in fresh water, it is thought to be extremely difficult to successfully landlock an American shad population given the hundreds of trials throughout the United States that have failed (R. St. Pierre, Pennsylvania Wildlife Commission, personal communication). Whether Millerton Lake is unique in providing adequate conditions for American shad to complete their life cycle and prohibit the seaward migration of their young, or if a similar situation may be found in southern Idaho reservoirs where introductions of the species is being considered needs to be determined.

Millerton Lake is 22.4 km long. The upper 2/3 of the lake is a narrow winding canyon 6-20 m deep, with granite boulder substrate and water velocities between 0.2 to 0.6 m/sec. Water temperature in the upper arm of Millerton Lake ranges from 11 to 17°C during spawning (16 to 18°C in August) and drops below 6°C in January and February. The lower lake widens to 2.8 km wide, with a maximum depth of 79 m. It stratifies in April with the thermocline close to the surface (2-6 m). Surface temperatures range from 14 to 30°C, with the highest temperature occurring in July and August. Hypolimnion temperatures range from 6 to 17°C. A change in water temperature of as much as 10°C occurs at the convergence point (the point where the cooler water of the upper arm plunges beneath the warmer stratified water of the lower lake) (Ecological Analysts 1982).

Brownlee Reservoir is 92 km long, with a mean width of .8 km and a maximum depth of 92 m. The upper 23 km of the reservoir is relatively shallow and river like. Temperatures during May and June are 14 to 21°C. The remaining 69 km of the reservoir are deep and currents are weak. The lower portion of the reservoir stratifies by early June, with the thermocline occurring at around 45 m. Surface water temperatures in the reservoir ranges from 15 to 25°C from May to October. Water temperature in January ranges from 3.3 to 5.5°C). A change in water temperature of up to 2.7°C occurs at the convergence line where the cooler river water meets the warmer stratified water. (Ebel and Koski 1968).

Water temperature is a major factor in determining whether fish will remain in a system. It appears that Brownlee Reservoir and Millerton Lake are similar except for winter temperature. However, it is not clear whether the temperature range reported for the lake portion of Millerton Lake is annual or summer only. If temperatures in Millerton Lake do not drop below the reported range, this reservoir offers a more favorable winter habitat than Brownlee Reservoir would.

A second factor that should be considered in determining whether shad will over-winter in the reservoir is flow. Because of the difficulty encountered by other anadromous species with similar outmigration behaviors, shad too may have problems leaving the reservoir. Although, if there are not sufficient temperature refuges in Brownlee, fishes that do not leave the system may die anyway.

Should the shad stay in the reservoir and survive the winter, there appears to be sufficient spawning habitat available, and the shad may be capable of maintaining a self-sustaining population in Brownlee Reservoir.

TRANSPORTING AND HANDLING AFRICAN SHAD

Since spawning habitat appears to be available in Brownlee, the most efficient method of planting American shad may be to transport adults in the reservoir. Trucking adult shad has shown value for re-establishing shad populations in the Connecticut River (Layzer 1979). When water temperatures were held below 14°C, mortality was low for all loads transported. For temperatures between 14 to 19°C, mortality was low only for loads of 40 or fewer fish (2271-L tank).

Although shad fecundities are high (100, 000 to 600,000), eggs do not mature simultaneously and normal egg-taking operations at a spawning site yield only 20,000 to 30,000 eggs per female. Therefore, if eggs were obtained by this method it would take about 1,800 females to produce the same number of eggs presumable laid by about 200 females trucked (Layzer 1979).

First feeding larvae are very sensitive to food depravation, and successful transition of this stage is critical to successful shad culture (Wiggens et al. 1985). Planktonic food must be present in sufficient abundance with respect to time and place to meet the demands of young fish when they first seek natural food after absorbing their yolk sac (Pearson 1952).

Richard St. Pierre, Pennsylvania Wildlife Commission, suggested planting young American shad after they pass the critical point of first feeding in a hatchery *environment.* This would ensure better survival of the young and would be especially important if planktonic food were limited in Brownlee.

Transporting and handling young American shad is difficult (Chittenden 1971). Young fish cannot withstand handling associated with counting, seining, or transfer. Seining shad resulted in 80-90% being too highly stressed for transport. However, effects of handling and seining stress can be reduced significantly by using a 4% saline solution (Meinz 1978).

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Appendix B. Letter of inquiry regarding American Shad and responses received.

also sent to: Joseph Blum, WA; Robert Tawstron, CA; Smokie Holcomb, FL; Mike Gennings, GA; Brock Conrad, SC Fred Harris, NC; Jack Hoffman, VA; MD; Charles Lesser, DE; Delano Graff, PA; Kenneth Wick, NY; Robert Jones, CT;
Randall Fairbanks, MA; Angelo Incerpi, VT; Duncan McGinnis, NH; Peter Bourque, ME.

October 15, 1989 Dear

Sir:

The Idaho Department of Fish and Game is currently investigating the potential use of American shad, Alosa sapidissima, to supplement the forage base in select large reservoirs. At this time, we are focusing on the idea of stocking adult shad and allowing natural reproduction to provide a pelagic prey base of YOY shad. The information available in the literature on this type of forage supplementation appears limited, so we are soliciting assistance from other agencies which may have some experience with American shad. Specifically, we are looking for information on:

1. Any landlocked populations and how they were established and stocking rates?
2. The value of American shad as forage in fresh water and for what species?
3. Interactions between adult and juvenile shad and game fish.
4. Food habits of juvenile and adult American shad.
5. Methods for collecting and transporting adults.

We recognize the lack of information on landlocked populations , so any data on American shad as forage in streams would also be of interest. Because American shad are not currently found in Idaho waters, we need to carefully assess the potential risks and benefits of introduction. I would appreciate your routing this letter to the appropriate staff.

If you would like a report of our findings, please us know. Responses may be sent to Jeff Dillon, Idaho Department of Fish and Game, 868 E. Main, P. O. Box 428, Jerome, ID 83338, or you may call him at 208-324-1137.

Thank you for your assistance.

Sincerely,

Virgil Moore

Virgil K. Moore
Fishery Research Manager

cc: Reiman Dillon

VKM:mw

STATE OF CONNECTICUT
DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF FISHERIES & WILDLIFE
MARINE FISHERIES OFFICE
P.O. BOX 248
WATERFORD, CT 06385

November 9, 1989

Mr. Jeff Dillon
Idaho Dept. of Fish & Game
886 East Main
P.O. Box 428
Jerome, ID 83338

Dear Sir,

As the biologist in charge of Connecticut's current American shad studies, I was given your letter of 10/15/89 to respond to. Unfortunately, I don't have much information to give you. Conversations with other staff members have produced no knowledge of any landlocked populations of American shad. Since the shad reach such large size and are only in freshwater for the first six months of life, little is known of their value as forage fish. One study on game fishes in the Connecticut River suggested that they were little utilized in comparison to the year-round available spottail shiner. I am sure that smallmouth bass, largemouth bass and northern pike in the freshwater reaches, and possibly striped bass and bluefish, all consume clupeids at some time, but the extent is unknown.

Food habits of juvenile shad are quite variable with fish consuming all variety of available insects and riverine zooplankton. Adult shad are not thought to feed in freshwater. The Connecticut River has been used in the past as a source of adult prespawned fish for many east coast river restoration programs. Fish have been collected by gill nets, haul seines and at the elevator fish lift at the Holyoke Dam. I have taken the liberty of enclosing a management plan that Victor Crecco and I wrote on American shad. It contains some interesting material that may be of value.

Sincerely,

Thomas Savoy
Fisheries Biologist

cc. Pete Minta

(203) 443-0166

Phone:
165 Capitol Avenue • Hartford, Connecticut 06106

STATE OF DELAWARE
DEPARTMENT OF NATURAL RESOURCES
& ENVIRONMENTAL CONTROL
DIVISION OF FISH AND WILDLIFE
89 KINGS HIGHWAY
P.O. BOX 1401
DOVER, DELAWARE 19903

OFFICE OF THE
DIRECTOR

October 30, 1989

Mr. Jeff Dillon
Idaho Dept. Fish and Game
868 E. Main
P.O. Box 428
Jerome, ID 83338

Dear Mr. Dillon:

Mr. Moore's request for information on landlocked herring was forwarded to me for reply. Delaware has no large reservoirs nor landlocked American shad. However, we have used landlocked alewife (Alosa pseudoharengus) to provide a forage base for largemouth bass and striped bass X white bass hybrids in a 189-acre impoundment.

Landlocked alewife were obtained from Lake Hopatcong (N.J.) and stocked annually from 1979-1981. Spawning of alewife was documented in 1981 when post-larvae were collected. An evaluation of alewife stocking and impact on gamefish populations was conducted from 1979-1984. Surveys since 1984 have monitored the alewife population but focused primarily on the largemouth bass and striped bass hybrid populations. Use of alewife as forage were documented via stomach analyses from 1983-1987. This information is available in Federal Aid reports F-32-R and F-35-R.

If you have any questions please call (302-736-4782). I would be interested in a report on your findings.

Sincerely,

Cathy Martin

Catherine C. Martin
Fisheries Biologist

CCM/mh

FARRIS BRYANT BUILDING
620 South Meridian Street
Tallahassee, Florida 32399-1600
(904) 488-1960

November **1, 1989'**

Mr. Virgil K. Moore
Fishery Research Manager
Idaho Fish and Game
600 South Walnut/Box 25
Boise, Idaho 83707

Dear Mr. Moore :

Your letter concerning American shad was referred to my office for reply.

There has been very little scientific work on American shad in Florida. We do have anadromous runs in the spring time in three major rivers; St. Mary, Nassau and St. Johns. After spawning, larval shad and fingerlings may fulfill some forage requirements as they descend rivers, although transient and possibly unstable in value. The presence of adult shad in freshwater systems is of short duration and likely nonsignificant in population interactions with resident species. There is no information available on the subject of freshwater stocking in our state.

If I may be of further service to you, please contact me.

Sincerely,

Forrest J. 4i1a're, Chief Bureau
of Fisheries Research

FJW/dls
FSH 4-3
moore.109

Georgia Department of Natural Resources

J. Leonard Ledbetter, Commissioner

Leon Kirkland, Director, Game and Fish Division
Fisheries Section
Route 3, Box 75
Fort Valley, Georgia 31030
912/825-6354

October 4, 1989

Mr. Jeff Dillon
Idaho Dapartment of Fish and Game
868 E. Main
P.O. Box 428
Jerome, ID 83338

Dear Mr Dillon:

I have a few comments regarding your request for information on landlocked American shad. These fish do of course occur in all of Georgia's Atlantic coastal rivers, however, I have personal knowledge of the distribution only within the Ocmulgee River of central Georgia.

American shad ascend the Ocmulgee to a low-head dam at Juliette, Georgia. Georgia Power Company has impounded a reservoir (Lake Juliette) on Rum Creek about one mile from the Ocmulgee River between Macon and Juliette. Most of the water for this reservoir is pumped from the Ocmulgee River and these pumping operations have resulted in the establishment of a small population of American shad in the lake. A few adults have been collected by electrofishing, but there is no evidence of reproduction or any expansion of this limited population. These are the only landlocked American shad within Georgia that I am aware of, although others may exist.

Further information on American shad in Georgia may be obtained from Ron Michaels, Georgia Game and Fish Division, Fisheries Section, 108 Darling Avenue, Waycross, Georgia 31501. Ron is conducting an extensive tagging study of American shad in Altamaha Sound. Good luck with your stocking program.

Sincerely yours,

Jimmy Evans

Jimmy Evans
Fisheries Biologist

New York State Department of Environmental Conservation
50 Wolf Road, Albany, New York 12233

Thomas C. Jorling
Commissioner

November 3, 1989

Mr. Jeff Dillion
Idaho Department of Fish and Game
868 E. Main
P.O. Box 428
Jerome, ID 83338

Dear Mr. Dillion:

Director Wich has asked me to respond to Mr. Moore's inquiry on the use of American shad as a freshwater forage base.

Anadromous populations of American shad occur in New York waters of the Hudson and Delaware Rivers. There are no landlocked populations in New York. I am not aware of any landlocked populations on the east coast. The potential for landlocking in upstream impoundments of the Hudson River appears high since adult fish can and do enter these impoundments through navigation locks. However, landlocked populations have never developed within any water of the Hudson system.

Young of year American shad contribute to the forage base of resident smallmouth and largemouth bass within the Hudson estuary and to the migratory striped bass population. In combination with juvenile blueback herring and alewife, shad certainly represent a major prey species in that system. We do not, however, have quantified data on relative utilization.

Adult shad are generally present only during their spawning run, primarily mid-April through May in the Hudson, and are not believed to be actively feeding at that time. This minimizes potential for predation or competitive interactions with plankton feeding young of other species. Any feeding competition associated with y.o.y. shad would be more than offset by their value as prey. I am not aware of any studies done in New York on the food habits of y.o.y. shad.

We collect adult shad via gill net and large (500-1,000 ft.) haul seines. Juvenile assessments in the Hudson are accomplished with beach seines and bottom trawls.

For information on transportation of adult shad, I suggest you contact Mr. Richard St. Pierre, U.S. Fish & Wildlife Service, P.O. Box 1673, Harrisburg, Pa. 17105-1673. Mr. St. Pierre is coordinating the Susquehanna River shad restoration program. This program involved the transfer of thousands of pre-spawned American shad for a series of years. Dick can provide you with details on handling techniques.

Your consideration of American shad as a landlocked forage base is interesting. In the northeast, the alewife (Alosa pseudoharengus) has been widely and very successfully introduced as an alosid forage for salmonids. Established landlocked populations are readily available for collecting brood stock. Maximum size and size at maturity of the landlocked alewife is much smaller than that reached by its anadromous counterpart and it therefore remains within preferred prey size. Reproductive capacity is very high, providing excellent predator production on a sustained basis.

Problems we have encountered with alewife are: (1) overpopulation leading to massive die-offs of aesthetic concern and (2) alewife predation/competition on pelagic larvae of desirable species - particularly walleye.

Unless growth of landlocked American shad (are there established landlocked populations?) is very substantially reduced compared to the anadromous variety, I would think a given stock might quickly outgrow its value as a forage base and, in turn, severely limit y.o.y. shad production through larvae predation.

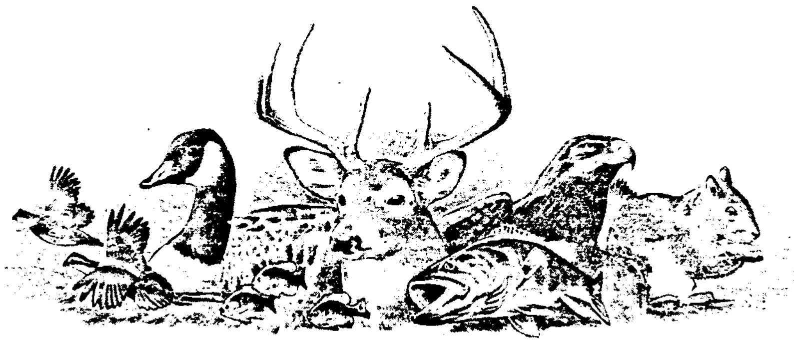
Good luck on your investigation. We would like to receive a copy of your findings.

Sincerely,

P. J. Festa

Patrick J. Festa
Supervising Aquatic Biologist
Inland Fisheries Section

PJF:ev



North Carolina Wildlife Resources Commission

512 N. Salisbury Street, Raleigh, North Carolina 27611, 919-733-3391
Charles R. Fullwood, Executive Director

November 2, 1989

Mr. Jeff Dillon
Idaho Department of Fish and Game
868 E. Main
P.O. Box 428
Jerome, ID 83338

Dear Mr. Dillon:

This letter is in response to your Departments request for information on the American shad. There are, to my knowledge, no landlocked populations of this specie in North Carolina and am unaware of any historic stockings into reservoirs. The American shad in North Carolina is limited in distribution to coastal rivers and streams and requires flowing water in larger tributaries for successful spawning. The primary forage species stocked in North Carolina is the threadfin shad (*Dorosoma petenense*) which would likely winterkill in your state. We have also, on a limited basis with little success, stocked blueback herring (*Alosa aestivalis*) and alewife (*A. pseudoharengus*) in attempts to provide forage for largemouth bass. Young American shad likely provide forage for game species (largemouth bass and estuarine species), but grow beyond the size range which can be utilized by most game fish found in North Carolina. The American shad provides a locally popular fishery for hook and line and gill nets. Shad are easily captured by electrofishing and transport well in aerated hatchery trucks.

Sincerely,

Kent Nelson

Kent Nelson, Coastal Research Coord.
803 Drexel Lane
Winterville, N.C. 28590

TO: Jeff Dillon
NOV 7 1989

COMMONWEALTH OF PENNSYLVANIA
PENNSYLVANIA FISH COMMISSION
Division of Fisheries Management
450 Robinson Lane
Bellefonte, PA 16823-9616

November 1, 1989

Virgil K. Moore
Idaho Fish and Game
600 South Walnut
Box 25
Boise, Idaho 83707

Dear Mr. Moore:

Your inquiry about American shad has been forwarded to me for a reply. Following are responses and comments relative to the five questions you asked.

1. There are no landlocked American shad populations in Pennsylvania and I do not recall having heard of any such populations anywhere. There are anadromous American shad in Pennsylvania's Delaware River basin and restoration effort are underway on the Susquehanna River basin. Pennsylvania and several other northeastern states do have landlocked populations of alewife (Alosa pseudoharengus). More about them below.

2. We have no information on American shad as forage in large reservoirs. We assume American shad in the Delaware River basin are utilized as forage by indigenous predatory fishes - smallmouth bass, walleye, esocids, catfishes, and trout, but I do not have stomach analyses to verify this.

3-4. I am unaware of any information on interaction between adult American shad and resident fishes. The adult American shad are in our rivers to spawn; presumably they feed little as food is rarely found in their stomaches during the spawning run. Juvenile American shad utilize our rivers during the first few months of their lives. The juvenile forage on zooplankters and progress to insects. As such they probably compete with the young of other fishes, many of which feed on the same food during their early life history.

5. American shad can be collected by a variety of methods - gill nets, haul seines, fish elevators, rod and reel. American shad, however, are extremely sensitive to being handled and high mortality rates can result from poor handling techniques. Other staff of the Pennsylvania Fish Commission have considerable experience handling both adult and juvenile American shad; for specific information I advise that you contact: Mike Hendricks, Benner Spring Fish Research Station, 1225 Shiloh Road, State College, PA 16801-8495.

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It might be of interest to you that landlocked populations of alewife exist and serve as forage for predators in several Pennsylvania lakes. Landlocked alewife adults at age 3 or 4 are 5 to 7 inches in length. Thus, they remain a desirable size forage for several years. Alewife are utilized as forage by smallmouth bass, largemouth bass, walleye, chain pickerel, northern pike, muskellunge, striped bass, channel catfish, crappie and trout. Most extensive utilization of alewife seems to occur in relatively shallow impoundments. Alewife appear to compete and adversely affect the growth of young centrarchid sunfishes, including black basses. Handling methods for alewife are similar to those of American shad.

I hope this information is useful. Please contact Mike Hendricks for handling details.

Sincerely,

Rick Hoopes

Rickalon L. Hoopes
Warmwater Unit Leader

cll

cc: Mike Hendricks
R. Snyder

Submitted by:

Jeff C. Dillon
Fisher Research Biologist

Debby Meyers
Fishery Technician

Approved by:

IDAHO DEPARTMENT OF FISH AND GAME

Jerry M. Conley, Director

Steven M. Huffaker, Chief
Bureau of Fisheries

Virgil K. Moore
Fishery Research Manager